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BRIEFER ARTICLES

NEW NORMAL APPLIANCES FOR USE IN PLANT PHYSIOLOGY III.[1]

(WITH TWO FIGURES)

In the two preceding articles I described several pieces of apparatus newly devised for educational work in plant physiology and explained the objects I have in view in their development. In brief I aim to provide for each of the principal physiological processes such apparatus as will be accurate in results, convenient in manipulation, and obtainable by purchase from a supply company. The company to which the manufacture has been delegated is the Bausch & Lomb Optical Co., of Rochester, N. Y. In the earlier articles I named the appliances "precision-appliances," which some, though not all of them are; they are, however, more properly *normal appliances*, which I shall henceforth call them.

VI. PHOTOSYNTHOMETER.

No fact in all the physiology of plants is more important, and hence more imperatively demands complete demonstration in botanical education, than the absorption of carbon dioxid by green plants in light, with the equivolumetric release of oxygen. There are simple ways of demonstrating the process in part, and somewhat complicated ways of demonstrating it completely; but hitherto there has been no simple method of demonstrating the entire process in one operation. This is effected, however, by the new photosynthometer described below, and illustrated in the accompanying *fig. 1*. It is called by this name for the reason that it permits photosynthesis (the quantity of the photosynthate being a function of the quantity of the gases absorbed and released) to be measured as well as demonstrated.

The instrument consists essentially of a pear-shaped plant-chamber set in a firm iron base, a graduated measuring tube with a small stop-cock at the upper end, and a connecting stopper furnished with a stop-cock of considerable bore. The total capacity of the apparatus when closed is exactly 102^{cc}, of which the 2^{cc} is for a shoot and 100^{cc} for the gases concerned. The proper amount of shoot is provided by selecting a small-leaved plant and pushing a branch down into a measuring-glass until it displaces exactly 2^{cc}

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[1] Continued from Bot. Gazette 39: 152. February 1905.

of water; the water-level is then noted on the stem, which is cut at this point under water, the shoot being later, when dried, placed upright in the chamber. (It hardly shows in the figure because of irregular reflections from the surface of the chamber.) Taking advantage of the fact that the shoot will carry on photosynthesis for a time in an atmosphere containing carbon dioxid in demonstrably large amount, even up to 10 per cent. or more, we add some selected percentage of that gas to the apparatus in this way. The measuring tube, with stop-cock closed, is inverted and filled with water of room-temperature, up to a figure of the graduation expressing the selected percentage, for the tube is graduated in cubic centimeters, which are, of course, percentages of the total gas capacity of the apparatus. The stopper is then placed on the tube, and its stop-cock closed; its hollow is filled with water and inverted in a pneumatic trough (or equivalent dish of water), which has been standing in the laboratory long enough to take the temperature of the air. The lower stop-cock is then opened and carbon dioxid from a generator is allowed to enter the tube, either from below or, as is most convenient, through the top of the tube. The admission of the gas may be perfectly controlled by cautious manipulation of the upper stop-cock, which is closed at the moment when the water has been wholly driven out to the bottom of the bore of the lower stop-cock, which point is held exactly at the water-level. The lower stop-cock is now closed, and the combination, which now contains exactly the desired percentage

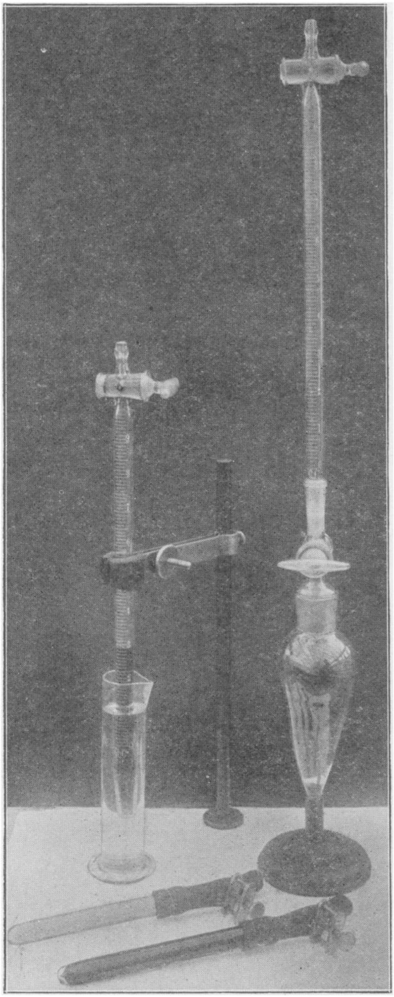

FIG. 1.

of carbon dioxid, is lifted from the water, shaken free from all adhering drops, and placed in position on the chamber. To prevent compression, and therefore the presence of too great a quantity, of air in the chamber when the stopper is pushed into place, tiny holes (visible in the figure), matching in stopper and chamber-neck, allow free release of such pressure, and the chamber is perfectly sealed by twisting the stopper a little. The lower stop-cock is then opened, permitting the carbon dioxid of the tube to diffuse into the chamber, a process hastened by its gravitational flow. The apparatus now contains obviously 2^{cc} of plant and 100^{cc} of gas, of which a known percentage (say 5, 8, or 10) is carbon dioxid, and the remainder is air. The instrument is now placed in a bright light (not direct sunlight) for three or four hours; then the lower stop-cock is closed (as shown in the figure), shutting into the tube a sample of the gas of the chamber at the close of the experiment. The analysis of this gas can be made at leisure, and is accomplished thus. The stopper and tube are removed and placed upright in the pneumatic trough, deeply enough to allow the stopper to be taken off without admission of air to the tube. The zero mark of the tube is then brought exactly to the water surface; the upper stop-cock is cautiously opened, permitting the water to rise slowly to the zero mark, when the stop-cock is again closed, shutting into the tube exactly 10^{cc} of the gas to be analyzed. First the quantity of carbon dioxid in the tube is determined, which is accomplished by aid of a reagent tube, of the form shown at the bottom of the figure. This tube, of glass, is provided with an extension of soft rubber tubing closed by a screw clamp, and it is filled completely to the clamp with a strong solution of caustic potash. It is slipped under the water of the pneumatic trough, with the clamp closed; the air, if any, is squeezed from the upper part; and the rubber is slipped over the lower end of the measuring tube which it grips firmly. The whole is then lifted from the water, the clamp is opened, the combination is inverted and the liquid is allowed to flow back and forth several times from one tube to the other, when it will completely absorb any carbon dioxid present. The clamp is then closed, the combination is slipped again under water, and the rubber tube is pulled off, when the atmospheric pressure will instantly force up the water to the exact extent of the carbon dioxid absorbed, permitting the amount, and hence the percentage, to be read off directly. Next a determination of the percentage of oxygen present is made. This is effected by a precisely similar method, using another reagent tube containing pyrogallate of potash, freshly made up in the usual manner. A few inversions of the combination will result in absorption of all the oxygen, and the water-level in the tube when the rubber is removed will give directly the percentage originally present. Some slender vessel may then be slipped under the tube which is removed and supported as shown by the figure.

Thus may the gas exchange in photosynthesis be demonstrated accurately, completely, logically, and conveniently.

In studying the process with beginners, the demonstration is the more striking and conclusive to them if a second instrument is set up like (and beside) the first, but covered completely from light; while even a third, like these two except that it has no plant, may advantageously be added. The comparative analyses of the gases at the close of the experiment give results leaving nothing to be desired in logical demonstration.

For all ordinary purposes, water may be used in the pneumatic trough, its slight absorption of carbon dioxid being negligible; but for great accuracy mercury may be employed. Similarly the corrections for capillarity, vapor tension, etc., may for elementary demonstration be ignored, though in precise work they would be taken into account. Temperature and barometric pressure are compensated, obviously, by the method of use of the instrument.

A much larger instrument, capable of taking large leaves, branches, or even entire potted plants, but operated upon substantially the same principle, is now in advanced preparation and will be described later.

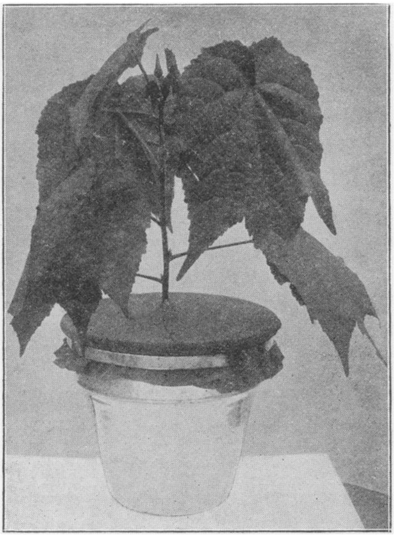

FIG. 2.

VII. ALUMINUM SHELLS FOR TRANSPIRATION EXPERIMENTS, ETC.

In transpiration studies with potted plants it is of course necessary to eliminate evaporation from pot and soil. There are many ways of effecting this, of which the best, perhaps, is the use of a tin cup or glass jar to cover the pot, and a roof of rubber sheeting. The advantage of this method over those in which the plant is wrapped in rubber, sealed in melted wax, etc., is this,—that the rubber roof may be readily detached from the can or jar and lifted, permitting a complete change of air to the roots when the plant is watered, thus contributing greatly to the health of the underground parts.

The aluminum shells here figured (*fig.* 2) are designed to provide light, neat, clean, and easily applied covers for pots on this principle. Flower pots are now made so nearly in standard sizes that it is possible to make the shells to fit them closely, and shells will be made for the present in 3-inch, 3½-inch, 4-inch and 5-inch sizes. To hold the rubber roof tightly to the shell, a tightly-fitting band or strap of aluminum, resting in a groove just below the strengthened top of the shell, may be drawn to any desired tightness by a convenient screw-nut, shown (though dimly) on the right in the figure. The rubber roof may be attached to the plant in any of the ways ordinarily used, but I find upon the whole the best method to be the following. In the middle of a proper-sized piece of medium-thick rubber-sheeting, a hole a little smaller than the stem of the plant is made with a cork-borer, and a cut is made with scissors from this to the margin of the piece. It is then placed around the stem, the cut edges of the central hole are stretched to overlap a little, sealed together with rubber cement and held clasped until this sets. Then a line of the cement is run to the margin, sealing one edge over the other. When fully set, the margin of the rubber is clasped to the shell, all surplus material is cut away, and a very neat and perfectly tight roof remains.—W. F. GANONG, *Smith College, Northampton, Mass.*